009

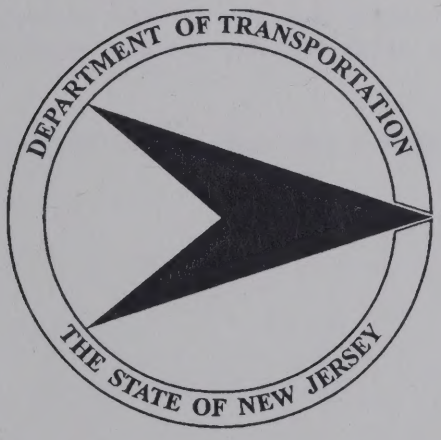
FHWA/ NJ 97-~~007~~
7680/4743

Demonstration Project No. 59-A

Fly Ash in Concrete: Final Report

by

Victor E. Mottola, P.E.
and
Anthony Chmiel, P.E.



Prepared by
New Jersey department of Transportation
Quality Assurance, Improvement, and Research
In Cooperation With
U.S. Department of Transportation
Federal Highway Administration

NJ
TA
455
F55
M6
1997
C.1

DISCLAIMER STATEMENT

"The contents of this report reflect the views of the author(s) who is (are) responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the New Jersey Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

NJ
TA
455
F55
M6
1997
c.1

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
97-007-7680/4743		

4. Title and Subtitle	5. Report Date
Fly Ash in Concrete: Final Report	December ~~1977~~ 1997
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Victor E. Mottola, P.E. and Anthony Chmiel, P.E.	97-007-7680/4743

9. Performing Organization Name and Address	10. Work Unit No.
New Jersey Department of Transportation 1035 Parkway Avenue Trenton, NJ 08625	11. Contract or Grant No.
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	Final Report 6/85 - 6/92
Federal Highway Administration U.S. Department of Transportation Washington, D.C.	14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the NJDOT Federal Highway Administration

16. Abstract

This report documents the construction and evaluation of 2 projects. (Rt. I-295 section 7G and Rt. I-78 section 1B & 6H) which contained up to 20% Fly Ash by weight as a substitute for cement in the Portland Cement Concrete.

After a short "learning curve" it was concluded that fly ash could be used in concrete to provide both cost and energy savings if the quality control measures were observed. Concretes containing fly ash developed compressive strength at a slower rate, but achieved significantly higher ultimate strength than the standard concrete.

Information learned in this study has been incorporated into the NJDOT standard specification.

17. Key Words	18. Distribution Statement
Fly Ash, Portland Cement Concrete Structures, Pavements entrained air contents.	No restriction

19. Security Classif (of this report)	20. Security Classif. (of this page)	21. No of Pages	22. Price
Unclassified	Unclassified	34	

Form DOT F 1700.7 (8-69)

TABLE OF CONTENTS

PART ONE: INTRODUCTION	PAGE
1.1 Objective	1
1.2 Background	1
PART TWO: PRELIMINARY INVESTIGATION	
2.1 Project Description	3
2.2 Climate	6
2.3 Bridge Geometrics	6
PART THREE: MATERIALS AND MIXTURE PROPORTIONS	
3.1 Fly-ash Data	10
3.2 Aggregate Material Data	10
3.3 Cement Data	12
3.4 Chemical Admixtures	12
3.5 Design Information and Procedure	12
PART FOUR: CONSTRUCTION INFORMATION	
4.1 Description of Site Preparation	15
4.2 Climate Conditions During Construction	16
4.3 Concrete Information	16
PART FIVE: FIELD AND LABORATORY RESULTS	
5.1 Unconfined Compression Tests	18
5.2 Slump and Air Entrainment Data	19
5.3 Data Analysis	21
5.4 Preliminary Conclusions	23

PART SIX: FURTHER STUDY **PAGE**

6.1 Additional Information 24

6.2 Project Description 24

6.3 Fly Ash Data 25

6.4 Aggregate Material Data 25

6.5 Cement Data 25

6.6 Chemical Admixtures 26

6.7 Design Information and Procedure 26

6.8 Collection and Analysis of Data 27

PART SEVEN: COST OF ALTERNATIVE MATERIALS 28

PART EIGHT: ENERGY ANALYSIS 30

PART NINE: CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions 32

9.2 Recommendations 33

PART TEN: REFERENCES 34

APPENDICES

A. Energy Consumption Calculations A1

INDEX OF FIGURES

Figure	Title	Page
1	Project Location	5
2	Clinton and Independence Avenue Structures	7
3	Broad Street Structure	9

INDEX OF TABLES

Table #	Title	Page
1	Aggregate Gradations	11
2	Materials used in Concrete for Project	13
3	Fly Ash Concrete Mix Designs	13
4	Regular Concrete Mix Designs	14
5	Compressive Strength Results	18
6	Statistical Analysis of Slump and Air Variability	20
7	Standard Deviation of Slump and Air Variability	22
8	Materials used in Concrete Mixes (Rt. I-78)	26
9	Fly Ash Concrete Mix Designs (Rt. I-78)	27
10	Fly Ash Concrete Mix Test Results	28
11	Cost Comparisons between Regular and Fly Ash Concrete	29
12	Energy Required to Produce Regular and Fly Ash Concrete	31

INDEX OF PHOTOS

Photo #	Title	Page
1	Independence Avenue Bridge	4
2	Clinton Avenue Bridge	4
3	Placing Concrete directly into Forms	17
4	Placing Concrete using 2 Yard Bucket	17

PART ONE: INTRODUCTION

1.1 OBJECTIVE

This report documents the construction and initial evaluation of two projects using Portland Cement Concrete containing fly ash. The study was intended to acquire needed information concerning the design methods, test procedures, construction techniques, and performance of fly-ash concrete. The overall performance of bridge footings, abutments, and roadway contains fly ash concretes was compared to standard control sections of regular concrete.

1.2 BACKGROUND

Renewed interest in the use of fly-ash as an ingredient in Portland Cement Concrete was generated when Congress passed the Resource Conservation and Recovery Act in 1976. One effect of this action was that all state highway agencies must allow the use of fly-ash in concrete in federal aid projects, if its use is not detrimental in any way to the material or the environment.

Fly-ash, a by-product of burning coal in electric generating power plants, is produced nationally at a rate of about 50 million tons per year. This material which was once discarded in our landfills, is now being used in various applications because of its pozzolanic properties.

These cementitous qualities make it attractive for use in certain highway applications.

One way fly-ash can be used is in Portland Cement Concrete, where it can replace a portion of the cement. Some benefits of this application are; reduced cost, lower heat of hydration, increased strength, and satisfying federal guide lines. However, it has also been established through prior use and research, that not all fly-ash cement combinations provide adequate performance. Thus, conditions under which fly-ash is used in concrete, specifications for the material used, concrete mixture proportioning, quality control procedures, and construction techniques must all be established and adhered to for successful applications.

PART TWO: PRELIMINARY INVESTIGATION

2.1 PROJECT DESCRIPTION

The bridge structures of Route I-295 Section 7G (New Construction) were to include fly-ash in all concrete except white concrete islands and curbs, prestressed beams, bridge decks, sidewalks, and parapets. In addition, bridge approach and transition slabs were also to contain fly-ash.

This project, located in central New Jersey, contains three bridges that span Route I-295. The Broad Street bridge and Independence Avenue structures (Photo 1) contained fly ash while the Clinton Street bridge (Photo 2) did not and was used as a control.

The project is located in Hamilton Township, Mercer County, New Jersey from south of Arena drive to Independence avenue. Mercer County is located on the Delaware River in central New Jersey (Figure 1).

Photo 2 Independence Avenue Bridge

Photo 3 Clinton Street Bridge

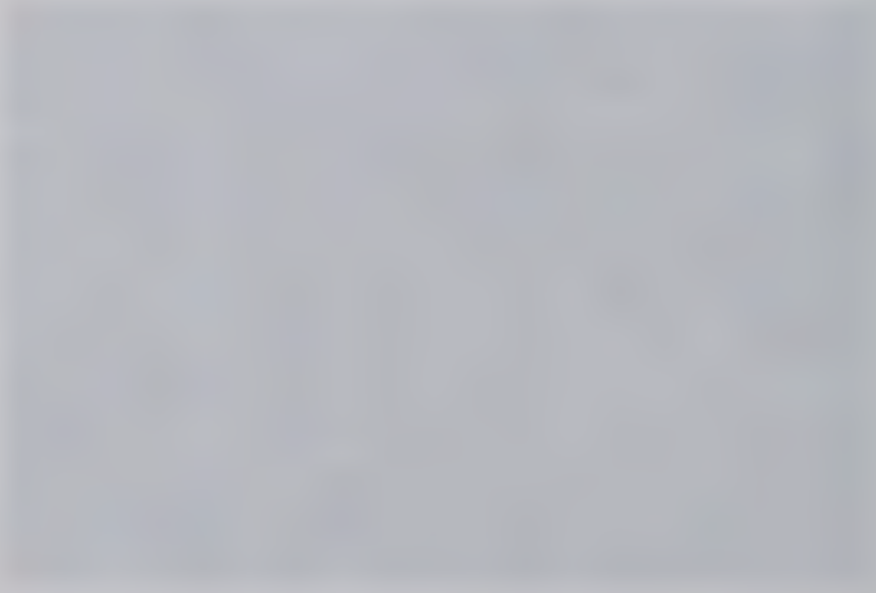


FIGURE 1 - PROJECT LOCATION

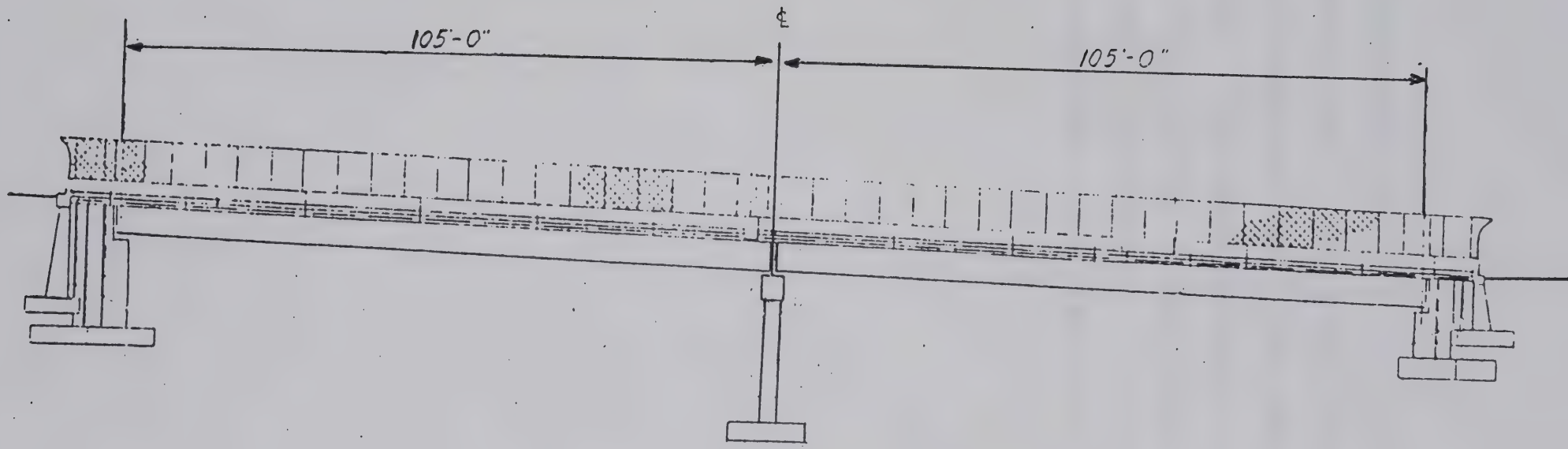
2.2 Climate

The climate in the vicinity of the test project is relatively mild, being moderated by the Appalachian Mountains to the west and the Atlantic Ocean to the east. Temperatures below zero and above 100 degrees Fahrenheit are rare. The average temperatures in January and July are 32 and 72 degrees respectively. The yearly average ambient temperature is about 52 degrees with maximum frost penetration of 28 inches.

Precipitation is fairly evenly distributed throughout the year, with the maximum amounts occurring during the late summer months. Most of the summer precipitation is in connection with local thunderstorms. Snowfall occurs infrequently, with single storms of 10 inches or more occurring about once every five years. Total average annual precipitation is 39 inches.

2.3 Bridge Geometrics

a) Clinton Street (Control) - The roadway consists of one 12 foot lane and one 8 foot shoulder and sidewalk in each direction. There are two end abutments and one center pier structure consisting of four, 3 foot diameter columns sup porting a pier cap. Resting on these structures are eight girders, creating two simple spans each 105 feet long (Figure 2).

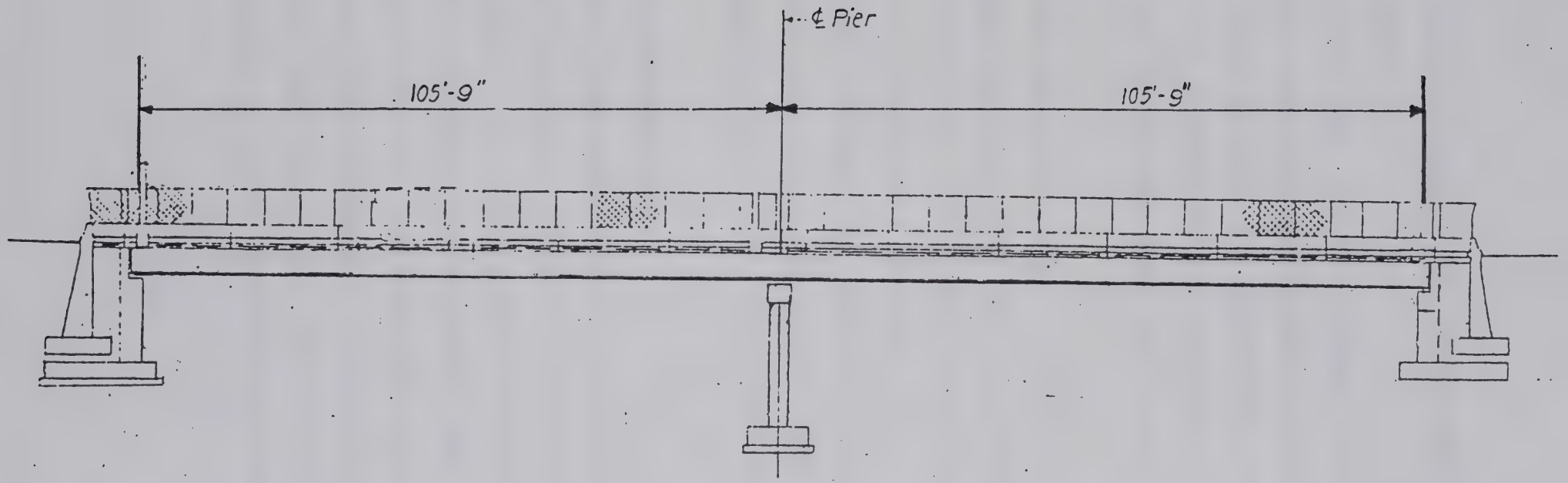


LONGITUDINAL ELEVATION

FIGURE 2 - CLINTON AND INDEPENDENCE AVENUE

b) Independence Avenue - Same as above (Figure 2).

c) Broad Street - The roadway consists of two 11 foot lanes in each direction with 12 foot outside shoulders and 10 foot sidewalks. The design is similar to the Clinton and In dependence avenue bridges in substructure, however the super structure design is different. In this case there are 8 continuous span girders used creating one 210 foot section. (Figure 3)



LONGITUDINAL ELEVATION

FIGURE 3 - BROAD STREET

PART THREE: MATERIALS AND MIXTURE PROPORTIONS

3.1 FLY ASH DATA

The fly ash used on the project was obtained form PSE&G's Electric Power Generating Station located in Trenton, New Jersey. This product was marketed by the American Fly Ash Company, 606 Potter Road, Desplaines, Illinois, which handles the quality control and distribution from an office at the plant.

The fly ash used was a type F designation, obtained from burning a Bituminous Coal from the West Virginia area. This ash was to conform to ASTM C-618, except that the loss of ignition was not to exceed 3 percent.

Before each shipment was delivered to the mixing site, laboratory tests were performed and the results were checked by DOT personnel to be in compliance with the specifications.

3.2 AGGREGATE MATERIAL DATA

The coarse aggregate used in the concrete was supplied by Trap Rock Industries, Moores station, New Jersey. The number 57 stone is a crushed angular trap rock (basalt or de base), having a gradation predominantly from 1/4 to 1 inch, a specific gravity of 2.77, and loose dry weight of 96 lbs/ft^3.

The sand used was supplied by Brick Wall Sand Company, Forked River, New Jersey and was a washed & processed material composed of quartz or other hard durable particles.

The material was predominantly angular in shape with a specific gravity of 2.65 and unit dry loose weight of 102 lbs/ft^3.

Table 1

Aggregate Gradations

Coarse Aggregate #57

Sieve Size	Specification (% Passing)
1 1/2	100%
1	95-100
1/2	25-60
#4	0-10
#8	0-5

Fine Aggregate

Sieve Size	Specification (% Passing)
3/8"	100%
#4	95-100%
#8	80-100%
#16	50-85%
#30	25-60%
#50	10-30%
#100	2-10%
#200	0-3%

No more than 45% retained between any two consecutive sieves and its fineness modulus not less than 2.3 for concrete.

3.3 PORTLAND CEMENT

The portland cement used in all the concrete mix designs with and without fly ash replacement was an Allentown Type II obtained from Evansville, Pa. The cement was to conform to ASTM Designation C-150 and is primarily for general use when moderate sulfate resistance or moderate heat of hydration is desired.

3.4 Chemical Admixtures

The chemical admixtures used in the concrete were manufactured by the Euclid Chemical Company of Cleveland, Ohio. These products were approved by the Department for use in all concrete at that time. The air entraining agent was Microair, water reducer WR-75, and Eucon was the retarder.

3.5 DESIGN INFORMATION AND PROCEDURE

The mix design criteria for all portland cement concrete was established in accordance with Section 914 of the New Jersey Department of Transportation Standard Specifications. The source of materials used and their locations are detailed in Table 2 with the mix designs used for each class of concrete listed in Table 3.

In the event of difficulties with fly ash concrete during construction, a substitute mix design in lieu of fly ash was prepared and can be found in Table 4.

Table 2

Materials Used In Concrete for Project

Material	Source	Location
Portland Cement	Allentown Type II	Evansville, PA
Sand	Brickwall Sand Co.	Lacy Twp.,NJ
Stone #57	Trap Rock Industries	Morris Station,NJ
AEA	Euclid Chem. - AIR Mix	Cleveland, OH
H_2O Reducer **	Euclid Chem. - WR-75	Cleveland, OH
Retarder	Euclid Chem. - Eucon	Cleveland, OH
Fly Ash	American Fly Ash Co.	Trenton, NJ

** Not used in any Fly Ash Concrete Mixes

Table 3

Fly Ash Concrete Mix Designs

Class	A-ALT	A	B	C
Cement #	580	540	500	480
Sand #	1150	1200	1250	1270
Fly Ash #	110	100	90	83
H_2O-gal	31.7	31.3	29.5	28.9
AEA-oz	6.2	5.8	4.2	3.9
Retarder-oz	27.6	25.6	23.6	22.0

Table 4

Regular Concrete Mix Designs

Class	A-ALT	A	B	C
Cement #	670	620	580	550
Sand #	1150	1200	1250	1270
Aggregate #	1900	1900	1900	1900
AEA oz	6.2	5.8	4.2	3.9
Retarder oz	27.6	25.6	23.6	22.0

PART FOUR: CONSTRUCTION INFORMATION

4.1 Description of Site Preparation

The construction contract was awarded to George Harms Construction Company of Farmingdale, N.J. in April 1985. Site preparation began in May of that year with the clearing of the roadway and shifting of traffic patterns on Broad Street and Independence Avenue.

New traffic patterns were instituted to keep the roads open while construction took place. The Broad Street bridge was started in June, and was constructed in two phases. The Westbound lanes were constructed first, with the Eastbound lanes following.

The Independence Avenue structure was started the same time as the Broad Street structure but this bridge was only one lane in each direction and did not require a two phase plan. Originally, traffic was to remain open during construction, however, difficulties with construction vehicles and traffic flow required the closing of the roadway.

At the end of the Phase One Broad Street construction, the Clinton Street bridge was started, detouring traffic around the area until its completion.

4.2 Climate Conditions During Construction

The climate in the vicinity of the test project ranged in temperature from 10°F in the winter to 95°F in summer. Relative humidity ranged from 30 to 95% throughout with occasional precipitation from snow in winter to severe thunder storms in fall, summer, and spring. During the construction of Phase 1-Broad Street, Hurricane Gloria roared ashore, dumping up to 6 inches of rain on the area.

4.3 Concrete Information

Concrete used for the project was provided by the Yardville Supply Company of Yardville, New Jersey. Proportioning of each 10 cubic yard batch was accomplished through the use of a computer aided scale which monitored the weights of each component. These components were then deposited and mixed in a transit mix truck from 50 to 75 revolutions. During this operation each individual driver added additional water while visually inspecting the concrete through the rear, in order to achieve the required slump.

The mixed concrete was then transported about five miles to the job site and was placed directly into forms using the trucks chutes (Photo 3), or where access was limited, using a two yard bucked positioned by a crane (Photo 4). In areas where the concrete was to be dropped into an excavated area, the concrete was poured into a funnel at the top of the forms and carried down through a flexible rubber tube.

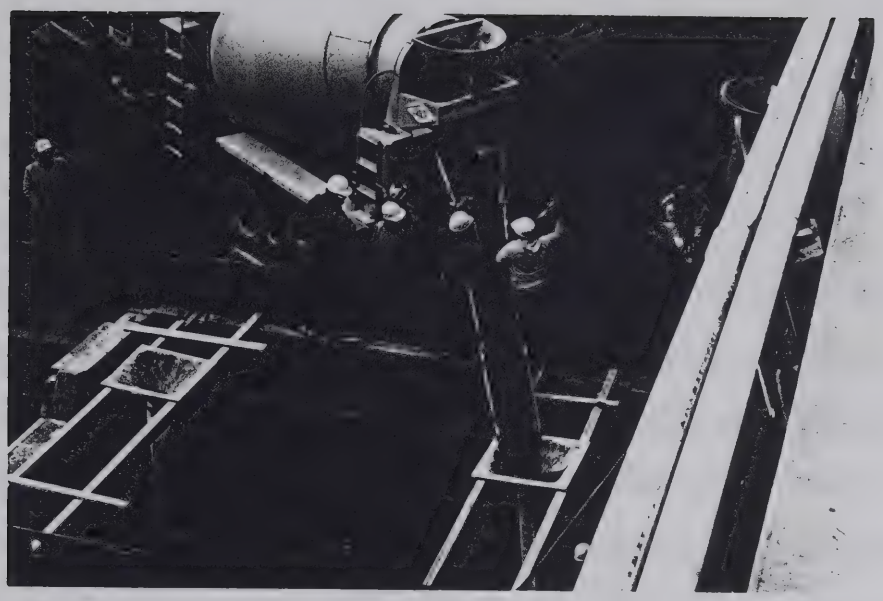


Photo 3

Placing concrete directly into forms

Photo 4

Placing concrete with 2 cubic yard bucket

PART FIVE: FIELD AND LABORATORY DATA

5.1 Strength Testing

During the construction the concrete was periodically sampled and molded into cylinders according to ASTM C-192. Samples were taken from both regular and fly ash concrete in each class and tested for strength according to ASTM C-39 after 1,3,7,14,28 and 56 days. These results were compared to determine the relative strength gain of fly ash concrete to regular concrete. The results indicate that fly ash concrete falls below the strength of regular concrete at early ages. This gap is closed within 7 days and ultimately exceeds regular concrete at 28 days or more. A sample of the strength tests performed on class B concrete can be seen in table 5.

Table 5

Compressive Strength Results

	Day Tests					
Concrete	1	3	7	14	28	56
Regular	1230	2480	3830	4212	4679	5285
Fly Ash	520	2050	3812	4645	5034	6118

5.2 Slump and Air Entrainment Data

In order to determine if there was any difference in consistency between regular and fly ash concrete, the slump and air content was closely monitored. The results of these tests, performed by Materials and Research personnel, indicated a higher than normal incidence of material not meeting the required specifications in both regular and Fly Ash concretes. These results, seen in table 6, show that the concrete slump with Fly Ash was out of the spec from the plant (Initial Slump) 14% of the time while concrete without Fly Ash was out of spec 10%. The initial failures were allowed to add additional water or air entraining agent and were retested after agitation. These results (final slump) indicated that concrete with Fly Ash was out of spec 26% of the time while concrete without Fly Ash was out of spec 14%. A similar accounting was done with the initial air/final air categories in Table-6.

Table 6

Statistical Analysis Results

Concrete With Fly Ash

Designation	Total Observation	% out of Spec
Initial Slump	220	14
Final Slump	50	26
Initial Air	194	21
Final Air	52	27

Regular Concrete

Initial Slump	204	10
Final Slump	36	14
Initial Air	201	21
Final Air	41	10

5.3 Data Analysis

To determine the degree of the problem encountered with controlling the consistency of the concrete, a detailed statistical analysis was performed in the following manner:

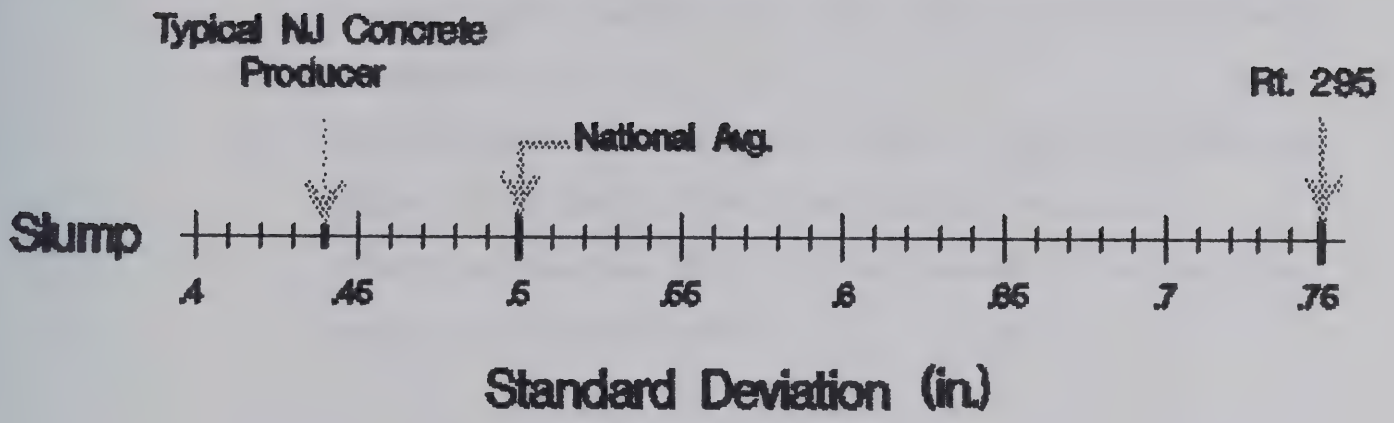
1) Historical data from the FHWA was collected and used as a benchmark for a national average for standard deviation of slump and entrained air content of concrete.

2) Data was gathered randomly from different concrete producers state wide, and analyzed yielding an mean and standard deviation for state contracts.

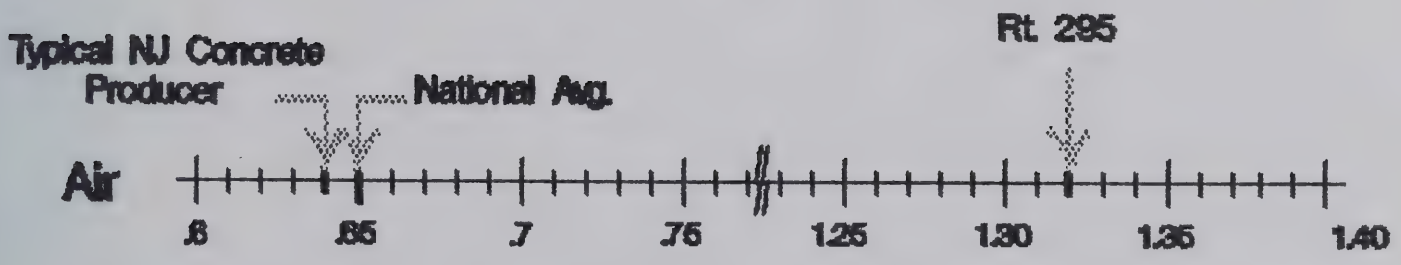
3) All data collected on the Route I-295 job was analyzed yielding a mean and standard deviation for the project.

The results of the statistical evaluation performed on the data revealed that the standard deviation of the route 295 project for slump and air entrainment far exceeded that of the national and state deviations. These results can be found in Table 7.

Table 7
Standard Deviations



Standard Deviation (in.)



Standard Deviation (%)

5.4 Preliminary Conclusions

The results of the investigation of fly ash concrete on Route I-295 yielded the following:

1) Strength development of fly ash concrete is slower than regular concrete during the first few days but catches up at seven days and yields higher ultimate strengths.

2) The variability of regular and fly ash concrete was higher than the national and state averages prompting another project be chosen to target the cause of the problems.

PART SIX: FURTHER STUDY

6.1 Additional Information

The results obtained during the Route I-295 project were in contrast to the published literature. The entrained air content of the concrete was difficult to control and the failure rate was above the average for New Jersey producers. Therefore, to determine the cause of this problem, another project was chosen with a different concrete producer.

6.2 Project Description

The additional project chosen for the evaluation of fly ash concrete was a roadway installation on Route I-78 Section 1B - 6H and Route 22 section 1G. The entire project was approximately 2.5 miles long and encompassed over 25,000 yd^3 of fly ash concrete.

The General Contractor was S.J. Groves and Sons from Norwalk, Ohio and the paving subcontractor was Chapen and Chapen Inc. of Houston, Texas. A portable central mix plant was set up 2 miles from the site at Alpha, New Jersey which serviced the entire project.

6.3 Fly Ash Data

The fly ash used on the project was obtained from PP&L's electric generating power plant located in Washingtonville PA. This product was marketed by the Ash Management Corporation, 420 W. Emmaus Avenue, Allentown, PA.

The fly ash used was a Type "F" ash obtained from burning a Bituminous Coal from the western Pennsylvania area. This ash was to conform to ASTM C-618 except the Loss of Ignition was not to exceed 3%. Each shipment was tested and checked to be in compliance with specifications before delivery to the job site.

6.4 Aggregate Material Data

The coarse and fine aggregate use in the concrete were supplied by Eastern Industries of Martins Creek, Pennsylvania. The #57 stone is a crushed gravel with a specific gravity of 2.70 and unit weight of 91 lbs/ft^3. The sand used was a C-33 designation with specific gravity of 2.55, unit weight of 91 lbs/ft^3, and fineness modulus of 2.90.

6.5 Cement Data

The Portland Cement used on the job was an Allentown Type II obtained from Evansville, Pennsylvania. This cement is the same type and source used on the initial project (Route I-295 Section 7G).

6.6 Chemical Admixtures

The chemical admixtures used on the project were supplied by the W.R. Grace Company of Cambridge, Massachusetts. The air entraining agent used was Davavair which conforms to ASTM C-260 and the water reducer was WRDA with HYCOL conforming to ASTM C-494. All compounds were added according to the manufacturers recommendations.

6.7 Design Information and Procedure

The mix design criteria for all fly ash concrete used on the project was established according to Section 914 of the New Jersey Department of Transportation Standard Specifications. These designs along with the materials used and locations obtained can be found in Tables 8 and 9.

Table 8

Materials Used in Concrete Mixes (Rt. I-78)

MATERIAL	SOURCE	LOCATION
Portland Cement	Allentown type II	Evansville PA
Sand	Eastern Industries	Martins Creek PA
Stone #57	Eastern Industries	Martins Creek PA
AEA	Daravair	W.R. Grace & Co.
Water Reducer	WRDA/HYCOL	W.R. Grace & Co.
Fly Ash	Ash Mgmt. Co.	Allentown PA

Table 9

FLY ASH CONCRETE MIX DESIGNS (Rt. I-78)

CLASS	A	
Cement	519 lbs.	
Sand	1107 lbs.	SG 2.55 FM 2.90
Stone #57	1867 lbs.	SG 2.70
AEA	6.3 oz.	
Water Reducer	31.7 oz.	
Fly Ash	92 lbs.	LOI < 3%

6.8 Collection and Analysis of Data

Initially , because of past data collected on fly ash concrete every truckload of concrete was tested for slump and entrained air at the plant, and every third truck at the site. When in the opinion of the engineer uniformity was achieved, the testing regularity was cut back to every 10th truck with random selections taken if any concrete looked suspicious.

In all over 250 tests were performed with results well within the NJDOT's acceptable range. These results can be found summarized in Table 10.

TABLE 10

FLY ASH CONCRETE TEST RESULT

Designation	Total Obs.	Out of Spec.	% out of Spec.
SLUMP	450	0	0
ENTRAINED AIR	450	0	0
Specifications:	Slump 2 +/- 1		
	Air 6 +/- 1.5		

PART SEVEN: COST OF ALTERNATIVE MATERIALS

The concrete used on the project was regular portland cement concrete and concrete containing fly ash. These materials are structurally equivalent therefore a cost comparison was made between each per yd^3.

The prices for the fly ash and cement at the time of the project were about $15.00 and $70.00 /ton respectively, and these comparative costs can be seen in Table 11.

This tabulation reveals that using fly ash at a 15% replacement level for cement, could yield on the average, approximately a $2.00/$yd^3$ savings.

Table 11

COSTS OF CEMENTIOUS COMPONENTS

REGULAR CONCRETE

CLASS	CEMENT	COST ($)
A-alt	670	23.45
A	620	21.70
B	580	20.30
C	550	19.25

FLY ASH CONCRETE

CLASS	CEMENT(#)/COST($)	FLY ASH(#)/COST($)	TOTAL COST
A-alt	580 / 20.30	110 / .83	$ 21.13
A	540 / 18.90	100 / .75	$ 19.65
B	500 / 17.50	90 / .68	$ 18.18
C	480 / 16.80	83 / .62	$ 17.42

COST COMPARISONS

CLASS CONCRETE	REGULAR CONCRETE	FLY ASH CONCRETE	SAVINGS USING FLY ASH CONCRETE
A-alt	23.45	21.13	2.32
A	21.70	19.65	2.05
B	20.30	18.18	2.12
C	19.25	17.42	1.83

PART EIGHT: ENERGY ANALYSIS

To determine the relative amount of energy consumed during the bridge construction, a comparison was made between the energy required to produce regular concrete verses concrete containing fly ash.

The production and construction energy inputs for each type of concrete were based on values prescribed in a report published by the Asphalt Institute.* Transportation energy inputs are based on gasoline required to transport the raw material to the concrete batching plant.

Table 12 presents the results of the energy comparison by classes of concrete used. The energy required for each type was converted to gallons of gasoline at 125,000 BTU/gal.and all calculations appear in Appendix A.

The results of this analysis show that using fly ash as a partial replacement for cement in concrete, saved on the average 2.65 gallons of gasoline/yd^3 over the project duration.

* See Reference #8

Table 12

ENERGY REQUIRED TO PRODUCE REGULAR AND FLY ASH CONCRETE

REGULAR CONCRETE			FLY ASH CONCRETE		
CLASS	BTU/YD^3	GAL.GAS/YD^3	CLASS	BTU/YD^3	GAL.GAS/YD^3
A-alt	3265610	26.1	A-alt	2898190	23.2
A	3072960	24.6	A	2746420	22.0
B	2921440	23.4	B	2594650	20.8
C	2803250	22.4	C	2499215	20.0

* 125,000 BTU = 1 Gallon of Gasoline.

CLASS	REGULAR CONCRETE (GAL.GAS/YD^3)	FLY ASH CONCRETE (GAL.GAS/YD^3)	SAVINGS USING FLY ASH CONCRETE (GAL.GAS/YD^3)
A-alt	26.1	23.1	3
A	24.6	22.0	2.6
B	23.4	20.8	2.6
C	22.4	20.0	2.4

PART NINE: CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

Fly ash can be and has been used successfully in portland cement concretes. Adding fly ash to the concrete can provide significant cost and energy savings, increases in ultimate compression strengths, as well as utilize a waste product.

However, as encountered on this project, fly ash can add another variable to the quality control of the mix and must be closely monitored to insure a consistent product. Current NJDOT specifications permit only high quality fly ashes and requires that additional quality control test be conducted at the start of each fly ash concrete project.

9.2 Recommendations

Concrete containing fly ash may be used as a substitute for regular concrete without cause for alarm if the following conditions are observed:

1) Class F fly ash should be used conforming to ASTM-618 except that the Loss of Ignition should not exceed three percent.
2) The fly ash substitution level should not exceed 15% of the total cemintitious material.
3) Shipments of fly ash from the source should be checked to verify compliance with specifications.
4) Careful monitoring of the slump and air entrainment is warranted due to the variability of the fly ash introduction into the cement matrix.
5) Due to the slower strength gain of concrete containing fly ash, form stripping should be delayed until adequate strength is achieved and varified by testing.

PART TEN: REFERENCES

1. William F. Boles P.E, Fly Ash Facts for Highway Engineer FHWA DP-59-8 July 1986.

2. Woodrow J. Halsted, Use of Fly Ash in Concrete, Transportation Research Board, Washington DC October 1986

3. John P. Loyd & Steven L. Young, Fly Ash Concrete-2298 State Study No. 81-03-3 July, 1983

4. W.J. Hend and J. Sajadi, Early Age Durability of Fly Ash Concrete West Virginia Department of Highways RP-69 August 1985

5. The Use of Fly Ash in Highway Construction (Selected papers from spring 1985 Seminars) FHWA, August 1985

6. Materials Division Laboratory Report on Fly Ash/Slag Evaluation the Port Authority of New York and New Jersey. July 1983

7. Woodrow J. Halstead, Quality Control of Highway Concrete Containing Fly Ash, NRMCA Publication No. 164, Max 1981

8. The Asphalt Institute College Road, MD; Energy Requirements for Roadway Pavements MISC-75-3, April 1975

APPENDIX A

CALCULATIONS FOR ENERGY CONSUMPTION

Materials

Produce Portland Cement = 7570000 BTU/Ton

Haul 65 mi x 2 @ 5,040 BTU/Ton = 655200 BTU/Ton

Total = 8225200 BTU/Ton = 4113 BTU/lb

Produce Crushed Stone @ 70000 BTU/Ton = 70000 BTU/Ton

Haul 15 mi x 2 @ 5,040 BTU/Ton = 504000 BTU/Ton

Total = 221200 BTU/Ton = 111 BTU/lb

Produce Sand @ 15000 BTU/Ton = 15000 BTU/Ton

Haul 50 mi x 2 @ 5040 BTU/Ton mile = 504000 Btu/Ton

Total = 519 BTU/Ton = 260 BTU /lb

Produce Fly Ash = 0 BTU/Ton

Haul 5 mi x 2 @ 5040 BTU/Ton mile = 50400 BTU/Ton

Total = 50400 BTU/Ton = 25 BTU/lb

Plant Operation are approximately equal for all concrete: therefore it will not affect the total significantly if omitted.

Mix Composition

Class A-Alt

With Fly Ash

Cement	(580 lbs)	(4113 BTU/lb)	= 2385540 BTU
Sand	(1150 ")	(260 ")	= 299000 BTU
Crush Stone	(1900 ")	(111 ")	= 210900 BTU
Fly Ash	(110 ")	(25 ")	= 2750 BTU
		Total	= 2898190 BTU

@ 125000 BTU/Gal of gas = 24 Gal of gas

Without Fly Ash

Cement	(670 lbs)	(4113 BTU/lb)	= 2755710 BTU
Sand	(1150 lbs)	(760 BTU/lb)	= 299000 BTU
Crush Stone	(1900 lbs)	(111 BTU/lb)	= 210900 BTU
		Total	= 3265610 BTU

@ 125000BTU/Gal of gas = 27 Gal of gas

Class A

With Fly Ash

Cement	(540 lbs)	(4113 BTU/lb) =	2221020 BTU
Sand	(1200 ")	(260 ") =	312000 BTU
Crush Stone	(1900 ")	(111 ") =	210900 BTU
Fly Ash	(100 ")	(25 ") =	2500 BTU
		Total =	2746420 BTU

@ 125000 BTU/Gal of gas = 22 Gal of gas

Without Fly Ash

Cement	(620 lbs)	(4113 BTU/lb) =	2550060 BTU
Sand	(1200 lbs)	(260 BTU/lb) =	312000 BTU
Crush Stone	(1900 lbs)	(111 BTU/lb) =	210900 BTU
		Total =	3072960 BTU

@ 125000BTU/Gal of gas = 24.6 Gal of gas

Class B

With Fly Ash

Cement	(580 lbs)	(4113 BTU/lb) =	2056500 BTU
Sand	(1250 lbs)	(260 BTU/lb) =	325000 BTU
Crush Stone	(1900 lbs)	(111 BTU/lb) =	210900 BTU
Fly Ash	(90 lbs)	(25 BTU/lb) =	2250 BTU
		Total =	2594650 BTU

@ 125000 BTU/Gal of gas = 20.8 Gal of gas

Without Fly Ash

Cement	(580 lbs)	(4113 BTU/lb) =	2385540 BTU
Sand	(1250 lbs)	(260 BTU/lb) =	325000 BTU
Crush Stone	(1900 lbs)	(111 BTU/lb) =	210900 BTU
		Total =	2921440 BTU

@ 125000BTU/Gal of gas = 23.4 Gal of gas

Class C

With Fly Ash

Cement	(480 lbs)	(4113 BTU/lb) =	1974240 BTU
Sand	(1200 lbs)	(260 BTU/lb) =	312000 BTU
Crush Stone	(1900 lbs)	(111 BTU/lb) =	210900 BTU
Fly Ash	(83 lbs)	(25 BTU/lb) =	2075 BTU
		Total =	2499215 BTU

@ 125000 BTU/Gal of gas = 20 Gal of gas

Without Fly Ash

Cement	(550 lbs)	(4113 BTU/lb) =	2262150 BTU
Sand	(1270 lbs)	(260 BTU/lb) =	330200 BTU
Crush Stone	(1900 lbs)	(111 BTU/lb) =	210900 BTU
		Total =	2803250 BTU

@ 125000BTU/Gal of gas = 22.4 Gal of gas

NJDOT RESEARCH LIBRARY
3 4310 00010 0761